THE AUSTRALIAN JOURNAL OF PHYSIOTHERAPY

VOLUME XXIV DECEMBER, 1978 NUMBER 4

POST-ROTATORY NYSTAGMUS IN HYPERACTIVE CHILDREN WITH SPATIAL AWARENESS PROBLEMS[1]

JULIE A. HARRISON, B.PHTY. (HONS.)

and

MARGARET I. BULLOCK, B.SC.APP., PH.D.

Department of Physiotherapy, University of Queensland

In recent years a great deal of attention has been focused on the problems presented by children diagnosed as having "minimal cerebral dysfunction", a term which refers to children exhibiting mild clinical neurological symptoms. In 1973, Wender expanded this definition, pointing out that hyperactivity, short attention span, impulsivity, poor school work, perceptual-cognitive dysfunction and poor neurological functioning and coordination are among some of the cardinal features of minimal cerebral dysfunction. Recently, the various professional groups involved in the management of these children have become much more aware of their problems and, as a team, are endeavouring to provide better rationale for treatment procedures and management.

In her studies of sensory integration and learning disorders Ayres (1974) has examined the manner in which sensory integrative processes develop and the ways in which they deviate in learning-disabled children.

Vital to the normal functioning of the central nervous system, sensory integration may be defined as the ability to organize sensory information ready for use. Integration not only occurs vertically between the cortex, basal ganglia, diencephalon, cerebellum, brain stem and spinal cord, but also horizontally between the two sides of the thalamus, brain stem and spinal cord.

The part played by the brain stem in sensory integration appears to be very important. Eccles (1966) has found evidence for multisensory convergence on single neurones in cortical and subcortical areas, while other researchers (Best and Taylor, 1973) have found a prevalence of these convergence networks in the mesencephalic reticular formation of the brain stem. Using this model of the polysensory neurones, Ayres (1972) suggests that not all sensory information is equally important in the integrative process and that tactile, proprioceptive and vestibular stimulation appear to be the most important inputs at the basic level since they may affect indirectly, the development of higher sensory modalities such as vision and hearing. However, she does not suggest an explanation of how this process occurs.

The role of the vestibular system is often overlooked because many of its functions take place largely below the level of awareness when compared to such senses as vision, hearing and touch. In fact, the vestibular system exerts a significant influence on locomotion, posture and muscle control and sensory integration. Ayres (1974) considers that this occurs because the vestibular system enables the organism to detect motion in the earth's

[1]Received December, 1977.

gravitational field, and through its interaction and integration with other sensory inputs, to comprehend whether there is motion of the body relative to the environment, or of the environment relative to the body, or a combination of both.

The mechanism allowing this detection of relative motion depends on connections between the vestibular system and other parts of the neuromuscular system. For example, connections between the vestibular system and the spinal cord and cerebellum act to coordinate and control movement and, because of these particular connections, vestibular stimulation can result in changes in muscle tone. The vestibular system also has a major influence on the control of the extraocular muscles and the appearance of nystagmus in a normal subject after stimulation of the vestibular receptors serves to illustrate this close connection. Ayres (1974) believes that it is this connection that allows the organism to perceive the correct relationship between the body's motion and that of the visual fields. However, Aarons and Goldenberg (1964) hold the view that correct perception of movement depends also on the connections with the spinal cord and cerebellum.

Apart from influencing these functions, the vestibular system can also indirectly affect psychological and behavioural attributes of an organism, for it is the vestibular system together with the tactile system, that is most concerned with the organism's spatial relationship to the earth. Ayres (1974) suggests that this relationship provides one of the most basic forms of physical and emotional security, and if there is dysfunction in the vestibular system it could lead to some psychological or behavioural problems.

In the light of current theories presented by neurophysiologists, our total perception of the world appears to be dependent on the coordination of motor responses involving postural mechanisms, the extraocular muscles and sensory information from the vestibular mechanisms (Best and Taylor, *op. cit.*).

Because the vestibular system has a large sphere of influence in the central nervous system, an abnormality of vestibular functioning could be manifest in different bodily functions. For example, evidence of vestibular dysfunction has been demonstrated by such signs as poor head righting, poor spatial perception and postural orientation, as well as a decrease in or absence of post-rotatory nystagmus following spinning. However, the ready elicitation, reproducibility and characteristics of vestibular nystagmus have made this one of the most convenient and reliable tools for examining central vestibular functioning (Bach-y-rita, 1972).

Post-rotatory nystagmus has been studied and reported by several researchers, including in infants by Mitchell and Cambon (1969) and Eviatar *et al.* (1974), and in normal children by Ornitz *et al.* (1974[a]). In 1974, Ayres noted that some children with learning difficulties have poor sensory integration combined with signs of vestibular dysfunction, including a reduced nystagmus (both in amplitude and in duration) and a lack of the dizziness which is normally experienced after rapid rotation. Watter and Bullock's (1975) studies of children with minimal cerebral dysfunction also revealed that some children showed an absent or decreased post-rotatory nystagmus after spinning. De Quiros' work in 1976 identified a relationship between vestibular disorders and other postural disturbances on the one hand and learning disabilities on the other. The experiments carried out by Ritvo *et al.* (1969) and by Ornitz *et al.* (1974[a, b]) on autistic children demonstrated a decreased duration of post-rotatory nystagmus, while Kantner *et al.* (1976) reported a prolonged post-rotatory nystagmus in a small number of children with Down's syndrome.

A test for nystagmus is commonly included in assessments of children with neurological problems, both by paediatricians and physiotherapists. To determine whether such a test is valid for hyperactive children with associated spatial awareness problems, a study was initiated within the Department of Physiotherapy, University of Queensland (Harrison, 1976). By comparing quantitatively the post-rotatory nystagmus in such children with that in a group of "normally active" children, the significance of any difference between the two groups could be determined.

When the head is flexed 30° from the vertical, rotation in the horizontal plane stimulates the horizontal canal most easily. For this reason and because horizontal nystagmus is the easiest type of nystagmus to record electrically with an electronystagmograph (ENG), the response to vestibular disturbance in this study was measured by the motor output (nystagmus) when the horizontal semicircular canals were stimulated.

SUBJECTS

Two groups of children were used for the comparative study. The first was drawn from a parent population of 43 children who had been diagnosed as having minimal cerebral dysfunction and as being hyperactive and who had been referred to the Department of Physiotherapy, University of Queensland, for assessment and treatment. Of these, 20 children who had demonstrated abnormalities in awareness of body space and who had received only minimal treatment for their condition were selected to form the experimental subject sample. Their ages ranged from four years two months, to nine years eleven months. Sixteen of the twenty subjects were boys.

By the process of stratified random sampling, a control group, matched exactly for age and sex, was selected from large parent populations at several local schools and preschools. Confirmed inclusion in the control group depended on the results of a screening neurological examination (Burns and Watter, 1974; Watter and Bullock, *op. cit.*) and on the medical history. Any significant abnormality in one or more of the ten tested areas, or any reported signs of nervous system dysfunction resulted in exclusion of the child.

APPARATUS

Previous researchers in this field have used simple techniques to produce and measure post-rotatory nystagmus. These include the Paine and Oppe technique (Paine and Oppe, 1966) and the use of a manually rotated scooter board (Steinberg, Russell and Rendle-Short, 1976).

However, for the purposes of this experiment, it was deemed necessary to use a more controlled means of producing the required vestibular stimulation. In order to obtain quantitative results and to decrease the number of variables, a mechanically driven rotating chair similar to the Barany chair used by several other researchers (Ornitz *et al.*, 1974[a, b]) was incorporated in this experiment to provide the acceleration and deceleration stimuli needed to elicit nystagmus. The chair seat was mounted on a drive shaft, which in turn was driven by a motor. This provided a means by which the chair could be revolved at a predetermined speed in either direction and accelerated or decelerated at a predetermined rate. The motor generated a speed of 1 revolution per 2 seconds and, from this speed, the braking system enabled the chair to be stopped in a quarter of a revolution.

The backrest of the chair was fitted with a padded head support which could be adjusted in two directions so as to match the head position of children in the age range of 2 to 12 years (*see* Figure 1). The vertical adjustment allowed for the variation in the sitting height of the child, while a rotatory adjustment ensured that the support and the child's head were inclined at such an angle that a line between the ear and the outer canthi of the eye was parallel to the floor. This provision, together with the fact that the central vertical axis through the child's head coincided with the axis of rotation of the chair, ensured uniform maximum stimulation to the horizontal semicircular canals.

In order to allow the nystagmus to be recorded accurately and permanently during all parts of the experiment, especially when vision was occluded, the eye movements were recorded electrically using electronystagmography (ENG). ENG uses the corneal-retinal potential, which is produced in humans by a positive charge on the cornea and a negative charge on the retina. Gay *et al.* (1974) comment that this potential varies from person to person so that it is necessary to calibrate the ENG for each subject in order to obtain suitable results for comparisons. If two electrodes are placed on the outer canthi of the eyes and a third reference electrode on the forehead as demonstrated in Figure 1, any gaze deviations cause a change in the direction of the potential difference at these sites that is related in almost linear fashion to the arc of deviation of the ENG recording needle. This deviation is printed by the ENG on moving chart paper.

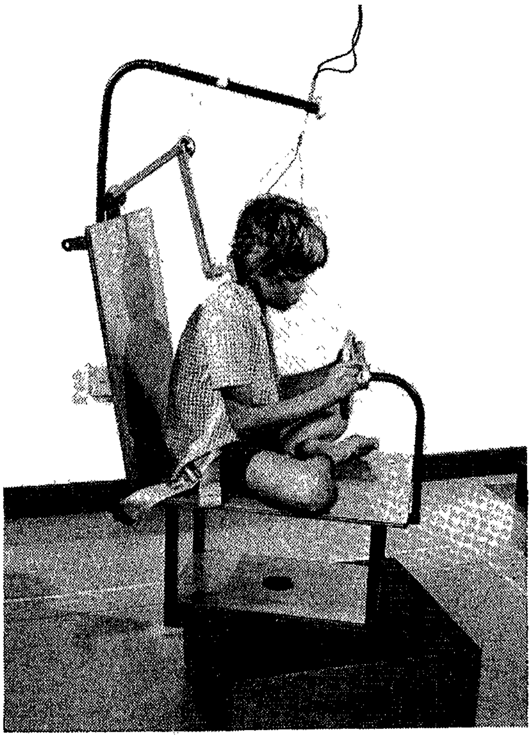

FIGURE 1

Subject on experimental chair in readiness for spinning.

The machine was calibrated for each child by asking the child to look alternately at two small dots 9 inches apart on the wall in front of him. These points subtended an angle of 10° between the subject's eyes. This calibration gave an indication of the distance the needle moved on the paper when the eyes were moved through an arc of 10°.

The paper speed was kept constant at 10 mm per sec. to ensure accurate measurement of time spans and nystagmus frequency. The ENG was designed so that movement of the eyes to the right caused an upward deviation of the recorder, that is, that right-beating nystagmus had its rapid phase upwards, and its slow phase downward, as seen in Figure 2a.

EXPERIMENTAL PROCEDURE

Before the commencement of any testing, the child, accompanied by one of his parents, was shown all of the equipment to be used and allowed to explore some of it while the experimental programme was explained to the parent, and the child's history taken.

All experimental testing was carried out by one physiotherapist and, as far as possible, the temperature and noise of the environment were maintained at a constant level.

A basic neurological assessment was carried out prior to a series of twelve tests for post-rotatory nystagmus. For each of these tests, the child was seated in a cross-legged position and strapped to the chair with a lap seat belt, while holding a "steering wheel" for security (*see* Figure 1).

The conventional Barany procedure of providing 10 revolutions in 20 seconds, followed by an abrupt deceleration to stop, was employed. The direction of revolution of the chair was reversed for each alternate trial, but in every case, the chair's spinning was so arranged that it stopped facing a blank wall to avoid any distractions.

The twelve trials were subdivided into three main groups, each depending on a "light" variable. During the first four trials, which were carried out in a lighted room, the subject was asked to keep his eyes open and to look at a cross on the wall when he stopped spinning, so encouraging visual fixation. In the second set of four trials, the child was blindfolded and the room was darkened. For the last four trials, performed in a lighted room, the subject wore 20 diopter spectacles and was asked to keep his eyes open. This technique allows light to fall on to the retina but, because of the child's inability to see very clearly through the glasses, visual fixation on completion of rotation is diminished.

A rest period of at least three minutes was allowed between the end of one group of rotations and the beginning of the next and one minute was allowed between each successive trial. If the child showed any signs of nausea, sweating, pallor or other autonomic signs, the testing was stopped immediately. If the child was very uncooperative or fearful of the situation, the number of trials was reduced by half.

Although a second adult was always present in the room and could assist if necessary, that adult remained out of the child's line of vision when the chair stopped.

The horizontal eye movements occurring on completion of rotation were traced on the recording paper of the ENG to give an accurate permanent record of each trial for later analysis.

RESULTS

The ENG recordings were separated into those relating to each of the three series of tests, so that comparisons could be made of the performance of the two groups of children in fixating while blindfolded and when wearing the glasses. Figure 2 illustrates a typical ENG recording of both per-rotatory and post-rotatory nystagmus obtained when the child was able to visually fixate (Figure 2a), and when fixation was prevented by using either a blindfold or glasses with 20 diopter lenses (Figure 2b).

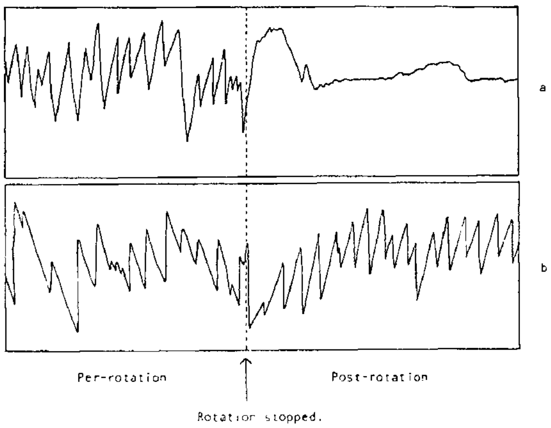

FIGURE 2

Comparison of nystagmus produced when
(a) fixation is allowed;
(b) fixation is prevented.

From the sets of ENG recordings, measurements were made of the duration, amplitude and regularity of the nystagmus and the total number of nystagmus beats. The two methods of measuring nystagmus developed by Ornitz *et al.* (1974[a, b]) to take into account the variability of children's nystagmograms, were used. Their definition of the "uninterrupted" duration score is the "duration in seconds from the end of rotation to the last nystagmus beat in a train of beats in which the time between the end of one beat and the beginning of the next does not exceed 1 second". On the basis of further research, this definition was qualified in two ways. They decided that the first nystagmus beat could start up to 5 seconds after the end of rotation and that a "disruption of the train of nystagmus beats longer than 1 second was accepted if the train of beats continued after the disruption for a period of time greater than the sum of the time of the disruption and the previous period of nystagmus". Ornitz's definition of the "total" duration score relates to "the duration in seconds from the end of rotation to the end of the last beat in a train of three consecutive beats regardless of earlier disruptions in the nystagmogram".

The mean and the standard deviation of both the "total" and the "uninterrupted" durations were calculated for the two groups of subjects. Table 1 compares these figures for each of the three series of tests.

To test whether there was a significant difference between the means of the two sets of results, a student "t" test was performed. For the sample size of 20 in each group, there was a 99% probability that the samples were different if "t" was greater than 2.7 and a 99.9% probability if "t" was greater than 3.55.

Examination of Table 1 reveals that visual fixation suppressed post-rotatory nystagmus in both the control and experimental groups, an observation which has been made previously by several researchers (Collins *et al.*, 1961; Ritvo *et al.*, *op. cit.*; Ornitz *et al.*, 1974[a, b]).

In all subjects, the duration of nystagmus was shorter when the child wore the glasses than when he was blindfolded. This finding is supported by the studies of Ornitz *et al.* (1974[a, b]), where impingement of the light on the retina was found to suppress the post-rotatory nystagmus.

Comparisons of the total number of beats, and the amplitude of the nystagmus revealed no significant differences between the two groups (*see* Tables 2 and 3). However, a significant difference in regularity of the ENG tracings was demonstrated, the children in the control group having a larger percentage of regular recordings than those in the experimental group (*see* Figure 3).

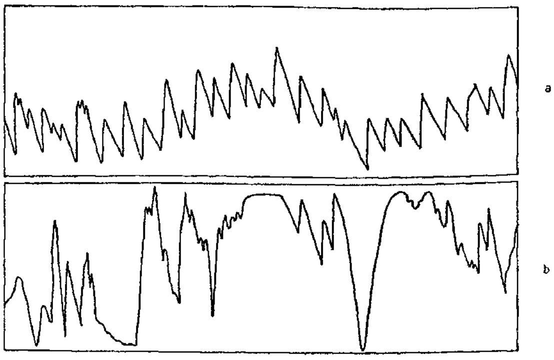

FIGURE 3
Comparison of nystagmus regularity:
a. "regular" pattern; b. "irregular" pattern.

There could be many reasons for the difference in regularity in the two groups. The experimental group may have greater difficulty fixating on an object and suppressing the nystagmus, or they may become more disoriented by the experience and thus move their eyes around more at the end of rotation, trying to equilibrate themselves to their environment. This is an interesting area which calls for more study, but the results of this small project do suggest that the vestibular response in normal children is more constant than that of children with hyperactivity associated with spatial problems.

TABLE 1

Test	*Control Group*		*Experimental Group*		"*t*"
	Mean	*SD*	*Mean*	*SD*	
1. Fixation					
(a) Total duration	6.8	3.9	6.8	3.1	0.03
(b) Uninterrupted duration	4.2	3.0	4.3	2.4	0.14
2. Vision Occluded (blindfolded)					
(a) Total duration	35.7	9.7	29.2	3.3	2.78*
(b) Uninterrupted duration	23.5	8.9	35.4	3.4	3.58*
3. Fixation prevented (20 diopter glasses)					
(a) Total duration	21.1	3.7	15.3	6.8	3.05*
(b) Uninterrupted duration	13.0	3.8	9.2	3.3	2.91*

Duration of Nystagmus in Seconds.

*Indicates a significant difference between the two groups.

TABLE 2

Test	*Control Group*		*Experimental Group*		"*t*"
	Mean	*SD*	*Mean*	*SD*	
1. Fixation	11.1	8.1	12.0	4.8	0.37
2. Vision Occluded (blindfolded)	47.0	12.7	39.5	9.3	1.97
3. Fixation prevented (20 diopter glasses)	27.4	7.8	25.4	9.8	0.62

Total Number of Nystagmus Beats.

TABLE 3

Test	Control Group			Experimental Group		
	Small	*Medium*	*Large*	*Small*	*Medium*	*Large*
1. Fixation						
(a) Per-rotatory	8.9	39.3	51.8	21.4	51.4	27.1
(b) Post-rotatory	71.7	24.5	3.8	70.8	21.5	7.7
2. Vision Occluded						
(a) Per-rotatory	6.8	72.9	20.3	17.9	73.2	8.9
(b) Post-rotatory	10.3	65.5	24.2	17.5	75.4	7.1
3. Fixation prevented						
(a) Per-rotatory	2.0	67.4	30.6	11.5	59.6	28.9
(b) Post-rotatory	17.4	67.4	15.2	9.6	82.7	7.7

Amplitude of Nystagmus Beats.
(Percentage of beats in each amplitude size.)

CONCLUSIONS

A comparative study of "normally active" and "hyperactive" children with observed vestibular and spatial problems showed that the latter group have a reduced duration of post-rotatory nystagmus following spinning, under specific experimental conditions where they are not able to fixate visually.

However, it must be noted that some children in the control group had a nystagmus of less duration than some subjects in the experimental group. For this reason, a test of nystagmus duration alone would be insufficient to discriminate between a "hyperactive" and a "normally active" child. Nevertheless, the study did demonstrate that children with some apparent neurological impairment have a tendency to exhibit depressed vestibular reactions.

Such results stress the importance of considering individual responses in conjunction with other neurological symptoms. Although a child with mild neurological impairment may not exhibit a marked abnormal response to particular sections of the neurological assessment, the results of a total assessment provide a complete and accurate picture of his sensory motor abilities.

While carried out on a small sample of subjects, the results of this trial suggest that further study of the vestibular system and more extensive observation of the nature of post-rotatory nystagmus could be useful to physiotherapists in their assessment and treatment of children with sensory motor dysfunction.

REFERENCES

AARONS, L. and GOLDENBERG, L. (1964): "Galvanic Stimulation of the Vestibular System and Perception of the Vertical". *Perceptual and Motor Skills*, 19 : 59-66.

AYRES, A. JEAN (1972): "Improving Academic Scores Through Sensory Integration". *Journal of Learning Disabilities*, 5 : 338-343.

AYRES, A. JEAN (1974): *Sensory Integration and Learning Disorders.* Western Psychological Services, Los Angeles.

BACH-Y-RITA, P. (1972): "Structural and Functional Aspects of Extraocular Muscles in Relation to Vestibulo-ocular Function". *Progress in Brain Research*, 37.

BEST, C. R. and TAYLOR, N. B. (1973): "Physiological Basis of Medical Practice". 9th edition. Williams, Baltimore.

BURNS, Y. R. and WATTER, P. (1974): "Identification and Developmental Assessment of Children with Neurological Impairment". *Australian Journal of Physiotherapy*, XX; 1 : 5-14.

COLLINS, W. E., GRAMPTON, G. H. and POSNER, J. B. (1961): "Effects of Mental Activity on Vestibular Nystagmus and the EEG". *Nature* (London), pp. 190-194.

ECCLES, J. C. (1966): "Conscious Experience and Memory". *Brain and Conscious Experience*, J. C. Eccles (ed.). Springer-Verlag, New York.

EVIATAR, L. and NARAY, I. N. (1974): "Maturation of Neurovestibular Responses in Infants". *Developmental Medicine and Child Neurology*, 16 : 435-446.

GAY, A. T., NEWMAN, N. M., KELTNER, J. A. and STROUD, M. H. (1974): *Eye Movement Disorders.* Mosby Co., Saint Louis.

HARRISON, J. A. (1976): *A Study of Post-Rotatory Nystagmus in Hyperactive Children with Vestibular and Spatial Problems.* Unpublished honours thesis, Department of Physiotherapy, University of Queensland.

KANTNER, R. M., CLARK, D. L., ALLEN, N. C. and CHASE, M. F. (1976): "Effects of Vestibular Stimulation on Nystagmus Response and Motor Performance in the Developmentally Delayed Infant". *Physical Therapy,* 56; 4 : 414-421.

MITCHELL, T. and CAMBON, K. (1969): "Vestibular Response in the Neonate and Infant". *Archives Otolaryngology,* 90 : 556-557.

ORNITZ, E. M., BROWN, M. B., MASON, ANNE and PUTNAM, N. H. (1974a): "The Effects of Visual Input on Post-Rotatory Nystagmus in Normal Children". *Acta Otolaryng.,* 77 : 418-425.

ORNITZ, E. M., BROWN, M. B., MASON, ANNE and PUTNAM, N. H. (1974b): "Effect of Visual Input on Vestibular Nystagmus in Autistic Children". *Archives of General Psychiatry,* 31; September : 369-375.

PAINE, R. S. and OPPE, T. E. (1966): *Neurological Examination of Children.* Spastics Society with Heinemann Medical, London, p. 135.

QUIROS, J. B. de (1976): "Diagnosis of Vestibular Disorders in the Learning Disabled", *Journal of Learning Disabilities,* 9; 1 : 39-47.

RITVO, E. R., EVIATAR, A., ORNITZ, E. M., MARKHAM, C. H., BROWN, M. B. and MASON, A. (1969): "Decreased Post-Rotatory Nystagmus in Early Infantile Autism". *Neurology,* 19 : 653-658.

STEINBERG, M., RUSSELL, J. and RENDLE-SHORT, J. (1976): "A Simple Method for Examining Post-Rotatory Nystagmus". *Australian Journal of Physiotherapy,* XX; 2 : 73-78.

WATTER, P. and BULLOCK, MARGARET I. (1975): *Evaluation of the Physiotherapy Management of Young Children with Minimal Cerebral Dysfunction—a Preliminary Study.* Department of Physiotherapy, University of Queensland, Research Report, 1/1978.

WENDER, PAUL H. (1973): "Some Speculations Concerning a Possible Biochemical Basis of Minimal Brain Dysfunction". In de la Cruz *et al.* (eds.), *Minimal Brain Dysfunction,* Annuals of the New York Academy of Sciences, 25; February : 18-28.